

Outline



- Background and objectives
- Nozzle overview and ground test results
- **Flight test approach and pilot-vehicle interface**
- Flight test execution and results
- Concluding remarks

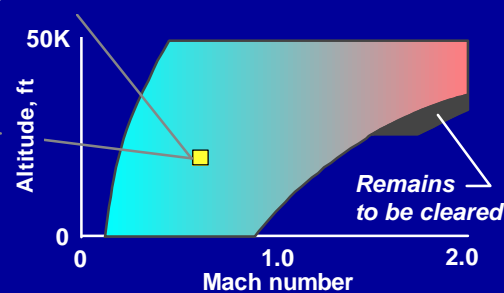
Good morning, I am Gerard Schkolnik, the NASA Chief engineer on the ACTIVE project. I will discuss the test approach used for the program and describe the flight test unique aspects of the pilot-vehicle interface.

PLA	Pitch	Yaw	Rate
PLF	± 5	0	40
PLF	± 10	0	40
PLF	± 15	0	40
PLF	± 20	0	40
PLF	0	± 5	40
PLF	0	± 10	40
PLF	0	± 15	40
PLF	0	± 20	40
PLF	± 20	0	80
PLF	0	± 20	80
Mil	Typ	Typ	Typ
Max	Typ	Typ	Typ

- Perform build-up in direction, vector angle, rate, and power setting on left engine
- Clear right engine primarily by similarity

- **Dynamic pressure expansion with alternating high and low altitude**

- Aggressive expansion approach (13 flight conditions)
- Target envelope cleared in less than 10 flights



- 1) functional operability and loads validation of the convergent and divergent actuation systems,
- 2) validation of the control software,
- 3) engine/nozzle compatibility, and
- 4) vector force model validation.

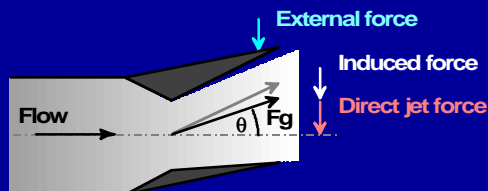
At each flight condition the build-up was performed initially in the pitch axis at PLF on the left engine, which was the most instrumented one,. An amplitude build-up followed to max angle utilizing classical doublet waveforms. This was followed by a similar build-up in yaw. Finally, max rate doublet were performed first in pitch and then yaw. This sequence was repeated at MIL and MAX power. Endpoints were verified on the right engine. Additionally, area ratio, fail-safe reversion, and simultaneous vectoring and throttle transient tests were performed at some flight condition.

Expansion started in the heart of the envelope 20K/0.6M and proceeded across the envelope with dynamic pressure steps no greater than 300 psf. Test points alternated between high and low altitude to sweep out the envelope. In total 13 flight conditions were identified requiring fewer than 10 flights. In large part this was due to the succesful outcome during the extensive ground test phase.

Nozzle Performance



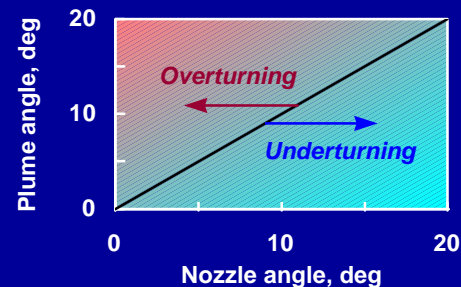
Vectoring Force Components



Objectives

- Identify internal induced effects
- Resolve discrepancies between predicted and measured vector nozzle loads

Induced Flow Turning



Approach

- Collect vector force, load, & pressure data during area ratio transients
- Identify most effective test technique

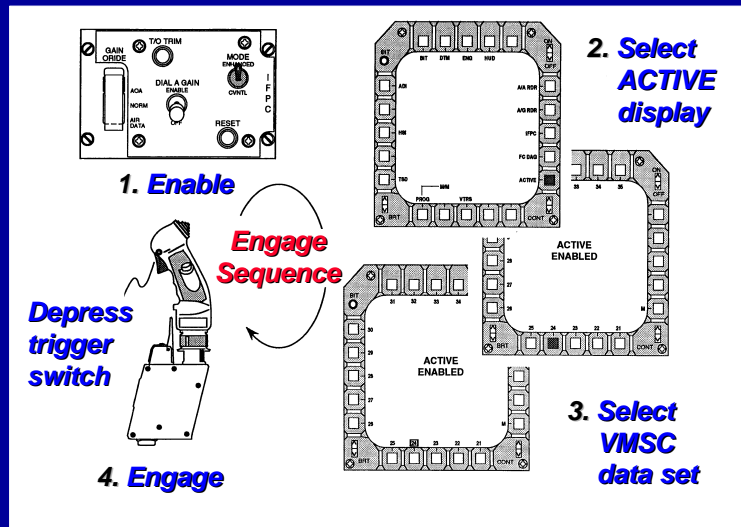
Nozzle performance testing evaluates how effectively the thrust vectoring system generates off-axis forces and moments.

This VECTORING FORCE DIAGRAM describes the components which collectively comprise the total force reacted by the nozzle. The total force can be broken down into external and internal components. The internal force can be further divided into 2 subelements the Direct jet force and the internal induced force. Possible contributors to the internal induced force are 1) thermal effects, 2) separation, 3) shock-boundary layer interaction, 4) flow leakage, etc.

The INDUCED FLOW TURNING DIAGRAM illustrates how the internal induced force can manifest itself. On the x-axis is the nozzle metal angle and on the y-axis is the plume angle. The black line indicates equality where the internal induced force is equal to zero. If the plume angle is greater than the metal angle overturning is encountered and if the plume angle is less than the metal angle underturning exists.

The approach for the nozzle performance testing is to collect vector force, load and pressure data at constant vector angles and flight conditions during area ratio transients. Vector force data is derived from strain gage measurements on the engine mounts. Acuator load data is derived from actuator pressure measurements. Gas path pressure data is measured directly by sensors located down along the divergent flaps. All of these techniques have their advantages and disadvantages are evaluated to estimate plume angle position.

VMSC ACTIVE: Engage



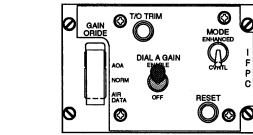
The ACTIVE PVI was based on the F-15E preproduction display architecture. The baseline system was augmented with 2 flight test pages on the MASTER MENU, the DAG and the ACTIVE displays.

The ACTIVE display allows the pilot to select 1 of 15 datasets stored in the VMSC. The ACTIVE dataset architecture is highly capable and flexible. Encoded in the ACTIVE dataset is the selection of: 1) either the Programmable Test Input (PTI) mode, or AdAPT research control law mode, 2) aerodynamic or propulsion control effectors commands, 3) piecewise linear and/or sinusoidal waveform characteristics, effector amplitudes, frequencies, and durations.

Currently, the dataset architecture provides the only means of generating vectoring commands, since the nozzles are not coupled into the inner loop control laws. Each load of 15 ACTIVE datasets can be easily reprogrammed between flights to accommodate entirely different test requirements.

To engage an ACTIVE dataset, 4 steps are required:

1. First the system is Enabled by moving the IFPC mode switch from CONV to ENHANCED. At this point the nozzles transition from the depowered, fail-safe, midstroke configuration to a powered configuration, actively commanded to zero vector angle and following the Optimum Area Ratio schedule. This was the normal mode flown, except for takeoff, landing and air refueling.
2. Second, select the ACTIVE display from the MASTER MENU.
3. Third, select an ACTIVE dataset by depressing one of the pushbuttons labeled 21- 35 , in this case, ACTIVE dataset 24 is selected.
4. Engage the dataset by depressing the trigger switch.



**Depress
trigger
switch**

4. Engage

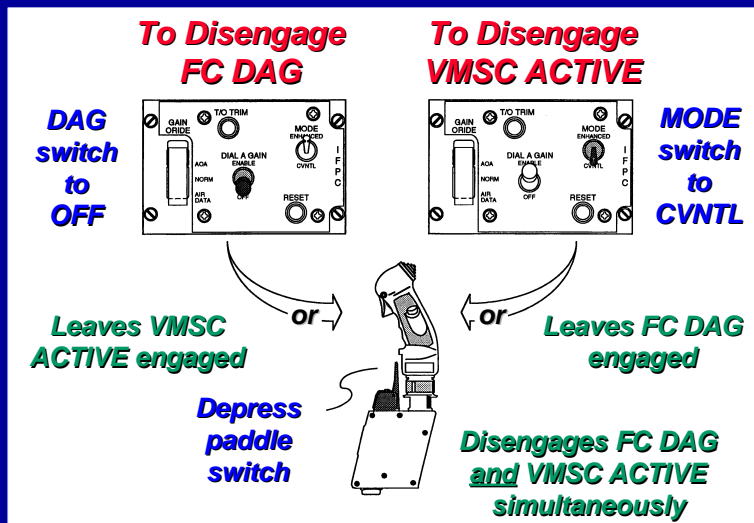
Engage Sequence

2. **Select DAG display**

3. Select DAG set

1. ENABLE
2. Select the DAG display.
3. Select a DAG set.
4. Engage via trigger.

Test Systems Disengage



Multiple options are available to the pilot to facilitate disengagement depending on the urgency. Under nominal conditions the pilot would allow the ACTIVE dataset to complete or would trigger off the dataset, and afterwards move the IFPC mode switch to “CONV” and the DAG switch to the “OFF” position. Under critical conditions the pilot would depress the paddle switch which would disengage the DAG and the ACTIVE dataset simultaneously, leaving the aircraft in the baseline non-vectoring configuration.